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## RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
DRAFT	10/02/2003	00-A	New document to establish the Hanford Facilities and Processes, Section 2, TBD. Initiated by Edward D. Scalsky.
10/02/2003	10/02/2003	00	First approved Issue of Revision 00. Initiated by Edward D. Scalsky.

## 1 ACRONYMS AND ABBREVIATIONS

2	Burnup	Depletion of fissionable material i.e., $^{235}\text{Pu}$
3	CEDE	Committed Effective Dose Equivalent
4	D&D	Decontamination and Decommission
5	EBR II	Experimental Breeder Reactor II
6	FP	Fission Products
7	FFTF	Fast Flux Test Facility
8	GETR	General Electric Test Reactor
9	HTLTR	High Temperature Lattice Test Reactor
10	HTR	High Temperature Reactor
11	kVp	kiloVolt potential
12	MeV	Million electron Volts
13	MW	Megawatts
14	Mint	Tritium
15	MTR	Materials Test Reactor
16	P-10	Tritium
17	PCTR	Physical Constants Test Reactor
18	PFP	Plutonium Finishing Plant
19	PFPP	Plutonium Fuels Pilot Plant
20	Pile	Reactor
21	Pit	A machined part of a nuclear weapon
22	PNNL	Pacific Northwest National Laboratory
23	PRCF	Plutonium Recycle Critical Facility
24	PRF	Plutonium Reclamation Facility
25	PRTR	Plutonium Recycle Test Reactor
26	PUREX	Plutonium-Uranium Extraction Plant
27	QA	Quality Assurance
28	QC	Quality Control
29	RECUPLEX	Recovery of Uranium and Plutonium by Extraction
30	REDOX	Reduction Oxidation Plant
31	RG	Rubber Glove
32	RMA	Remote Mechanical A Line
33	RMC	Remote Mechanical C Line
34	Slugs	Another name for fuel elements
35	TRIGA	Training Research Isotopes, General Atomics Reactor
36	TTR	Thermal Test Reactor

## **HANFORD SITE DESCRIPTION AND PROCESSES**

Construction of facilities at the Hanford Site, an area of approximately 600 square miles, commenced in Mar. 1943 when several major nuclear facilities were started. These included 105-B (Production Reactor); 221-T (Separation Facility); 305 (Test Pile); and 313 (Fuel Element Fabrication). The production reactors designed to produce plutonium by irradiating metallic uranium, were constructed in the 100 Areas located along the Columbia River on the north side of the Hanford site. The separation facilities were built in the 200 Areas located on a high plateau in the center of the Hanford Site. The fuel fabrication facilities, test reactors and research and development laboratories were built in the 300 Area located on the south side of the Hanford Site. The facilities discussed in subsequent sections represent those facilities out of more than 500 major facilities where nuclear activities were conducted. Note: Throughout this document, where a “\*\*” is included with a date – this indicates either there were two dates found (the most claimant-favorable was listed) or the actual year in the decade was not found in the documents. Where “UNK” is used, a date has not been found.

### **2.1 REACTORS**

Nine-graphite-moderated, light water cooled reactors were constructed near the Columbia River in the Hanford 100 Areas over a period of 20 years commencing in 1943 (Carlisle, 1996). The production reactors were used to produce plutonium by irradiating metallic uranium fuel elements with neutrons during the fission reaction in the reactor core. Other defense-related radionuclides that were experimented with included: irradiation of thorium to produce  $^{233}\text{U}$ , irradiation of depleted uranium to produce  $^{240}\text{Pu}$ , irradiation of neptunium targets to produce  $^{238}\text{Pu}$ , and irradiation of americium to produce medical grade  $^{238}\text{Pu}$ . These nine production reactors designated 100-B, C, D, DR, F, H, KW, KE, N were constructed in the B, D, F, H, K, and N Areas, respectively from 1944 to 1963. The first eight reactors at Hanford designated 105-B, C, D, DR, F, H, KW, and KE were similar in design utilizing a once-through light-water cooling system. The ninth reactor, 105-N, utilized a closed-loop light water cooling system. The years of operation and radionuclides of concern are shown in Tables A.1-1 and A.1-2 respectively in appendix A. External exposures are primarily due to the presence of activation and fission products (FP). During operation, entry was controlled into areas where high direct dose rates from photons and neutrons could occur. Internal exposures involving uranium, activation products, and fission products, were primarily limited to maintenance and refueling activities.

Additionally, there were seven physical testing, research and demonstration reactors operated at Hanford over a period of 40 years (Carlisle, 1996). Six Research and Test Reactors, located in the 300 Area were constructed and operated from 1943 to 1978. These include the 305 Hanford Test Reactor (HTR), Physical Constants Test Reactor (PCTR), Thermal Test Reactor (TTR), Plutonium Recycle Test Reactor (PRTR), Plutonium Recycle Critical Facility (PRCF), and High Temperature Lattice Test Reactor (HTLTR) (Newman, 1989). The Fast Flux Test Facility (FFTF Reactor) was constructed and operated from 1980 to 1993 in the 400 Area. The years of operation and radionuclides of concern are shown in Tables A.1-3 and A.1-4 in Appendix A.

#### **2.1.1 105-B, C, D, DR, F, H, KW, and KE Production Reactors**

The first three reactors (100-B, D, and F) were built in B, D, and F Areas starting in Aug, Nov. and Dec. 1943. The B reactor commenced operation in Sept. 1944. The D and F Reactors commenced operation in Dec. 1944 and Feb. 1945 respectively. In addition to producing plutonium for nuclear weapons, the reactors also produced polonium for use as a neutron source trigger or initiator in the weapons. By May 1945 four of the tubes in D Reactor were charged with bismuth slugs for polonium production. Construction of DR Reactor, located in D Area, was started in Dec. 1947 with startup

commencing in Oct. 1950. The H Reactor was constructed in H Area starting in Mar. 1948 with startup in Oct. 1949. Construction of C Reactor in B Area commenced in Jun 1951 with startup in Nov 1952. The KW and KE Reactors were constructed in KW and KE Areas starting in Nov. 1952 and Jan. 1953. They commenced operation in Dec. 1954 and Feb. 1955 respectively. These eight reactors were graphite moderated and single pass cooled using treated river water. The first three reactors (B, D and F) were the same design. The remaining five reactors (DR, H, C, KW and KE) were similar in design with the KE and KW reactors differing primarily in the number, size and type of process tubes, the size of the graphite stack, and the type of shielding.

The fuel elements were metallic uranium clad with aluminum. In 1960, confinement systems were incorporated in the first eight reactors and these reactors were shut down over a period of years starting in 1964 and ending in 1971. See Table A.1-1 for shutdown dates.

### **2.1.2 105-N Production Reactor**

Construction of 105-N (ninth production reactor) was started in N Area in 1959. The N Reactor design was based on the original graphite production reactors. However, it differed substantially from the first eight since it incorporated closed-loop cooling and it was the first Hanford reactor to incorporate a confinement system in the original design. It was designed to be a dual-purpose reactor (i.e. producing both plutonium and steam to be used to generate power). The dual-purpose reactor started producing plutonium in Mar. 1964 and electrical power some time later. The N reactor fuel was a tube-in-tube design consisting of a metallic uranium core surrounded by a thin zircaloy-2 cladding. The core consisted of an inner tube enriched to 0.95% U-235 and an outer tube enriched to either 0.95% or 1.25% U-235. From 1965 to 1967, tritium was produced at N-Reactor using fuel elements manufactured in the 333 facility. The N reactor was shut down in 1987.

### **2.1.3 305 Hanford Test Reactor**

The 305 Hanford Test Reactor (HTR) (also called the Test Pile) located in the 305 Building was the first reactor to operate at Hanford starting in 1943. It was operated until 1972 at a very low critical level (usually less than 50 W) to test fuel elements, fuel configuration, graphite samples and other materials for the production reactors. It was used as a quality assurance tool to house testing of samples of each lot of graphite, uranium, aluminum jacketing material, and other materials used in the large production reactors. The reactor consisted of a graphite pile and was air-cooled. It was removed from the 305 building in 1976-1977.

### **2.1.4 305-B Physical Constants Test Reactor**

The Physical Constants Test Reactor (PCTR) started operation in 1954. The 800 W test reactor was located in a shielded room in the 305-B building. The mission of the PCTR was to measure reactor changes as a result of use of different reactor fuels. Some plutonium contamination that occurred in the reactor room as a result of an accident could have been the source of minor internal exposure during cleanup. External exposure was negligible since the reactor was located in a shielded underground room and operated remotely. Operation was terminated in 1970.

### **2.1.5 305-B Thermal Test Reactor**

The Thermal Test Reactor (TTR) started operation in 1954. The 1 KW reactor was located in a shielded underground room in the 305-B building and operated remotely. The mission of the TTR was to measure thermal impact on fission cross sections. It functioned as an early and small version



of the HTLTR. External exposure was minimized since the reactor was operated remotely. Operation was terminated in the 1978.

### **2.1.6 309 Plutonium Recycle Test Reactor**

The Plutonium Recycle Test Reactor (PRTR), located in the 309 building, started operating in 1960. The PRTR was a 40 MW heavy-water-cooled and heavy-water-moderated reactor. The reactor was chosen for a large fuels diversification program known as the Plutonium Fuels Utilization Program. Tests were to be performed with various mixed oxide fuels using various methods of manufacture. As an example, tests were performed on a variety of powdered and pelletized fuels using plutonium oxide blended with uranium oxide and other metallic oxides. The fuel was a nominal 96% depleted uranium oxide and 4% plutonium oxide powder that was vibration compacted within the fuel pin. External exposure was minimized as a result of the remote operation and the shielding. Maintenance operations resulted in external exposure from activation and fission products. A high extremity exposure occurred when a worker picked up an irradiated steel pin. Tritium ( $^3\text{H}$ ) oxide was the principal internal exposure contaminant during normal operation. This whole body exposure was added into the external whole body dose summary (See sections 5 and 6 - Internal and External Dosimetry). The reactor was shutdown in 1969 after an accident resulted in contamination in the reactor. A sample of the contamination showed the major contaminant was  $^{95}\text{Zr/Nb}$ . Other contaminants included  $^{60}\text{Co}$ ,  $^{103}\text{Ru}$ ,  $^{106}\text{Ru}$ ,  $^{106}\text{Rh}$ ,  $^{140}\text{Ba/La}$ ,  $^{141}\text{Ce}$ ,  $^{144}\text{Ce}$ , and  $^{144}\text{Pr}$ .

### **2.1.7 309 Plutonium Recycle Critical Facility**

The Plutonium Recycle Critical Facility (PRCF), which was located in the 309 building, began operating in 1962. Tests were conducted in the PRCF to determine which geometrical arrangement of fissionable materials would work in a reactor. It was shut down in 1976.

### **2.1.8 318 High Temperature Lattice Test Reactor**

The High Temperature Lattice Test Reactor (HTLTR) was a 2 MW test reactor built in the 318 building in 1967 with operation commencing in 1968. The reactor consisted of a graphite cube located in a large shielded room and was operated at elevated temperatures up to  $1000^{\circ}\text{C}$ . The mission was to advance reactor physics technology. It was shut down in 1971 after 3-years of operation spanning 4 years during which time they operated with six different cores (i.e. three -  $^{233}\text{U}$ , one -  $^{235}\text{U}$ , one -  $^{238}\text{U}$ , and one -  $^{239}\text{Pu}$ ). Since the reactor was heavily shielded and operated remotely, external exposure was at background levels. There were no contamination incidents so internal exposure was negligible. The building and the shielded room were modified in the early 1980's and used as the new Hanford Radiation Calibration Facility (see section 2.5.8).

### **2.1.9 405 Fast Flux Test Facility**

The Fast Flux Test Facility (FFTF) was a 400 MW sodium-cooled test reactor located in the 405 building. It began start-up operations in Feb. 1980 in support of the fast breeder reactor program. The FFTF was used to test the irradiation of fuels and materials that would be used in a breeder reactor and to perform long-term testing of reactor components and systems. It was also used for the production of Medical Isotopes and research on space power systems. The external and internal exposures were at background levels. The facility was shutdown in 1994 and currently is waiting D&D.

## 2.2 FUEL SEPARATIONS FACILITIES

Seven separation facilities, B Plant, T Plant, U Plant, Reduction/Oxidation (REDOX), Plutonium-Uranium Extraction Facility (PUREX),  $\text{UO}_3$ , and C Plant, were constructed and operated in the 200-W and 200-E Areas from 1943 to 1993. The tritium processing facility was operated from 1949 to 1955 in the 108-B building located in the 100-B Area. Natural uranium and thorium fuel elements and lithium-aluminum (Li-Al) target elements were irradiated to produce Pu-239, U-233, and tritium, respectively. The spent reactor fuel was transported to the 200 Areas (*i.e.* Separations Areas) for processing. Initially spent fuel was stored in the reactor storage basins and the 212-N, 212-P, and 212-R buildings in the 200-N Area prior to processing in the fuel separations facilities (e.g. 221-B 221-T, REDOX and PUREX). The irradiated lithium-aluminum target elements were transferred to the 108-B building, 100-B Area for processing. Irradiated thorium fuel elements were processed in the PUREX Plant to recover U-233 in two separate campaigns that occurred in 1966 and 1971. External exposures were primarily high-energy betas and photons in the separations facilities associated with fission products (FP). Internal exposures, primarily associated with contamination incidents, could be due either to FP and/or plutonium. The years of operation and radionuclides of concern are shown in Tables A.2-1 and A.2-2 respectively in Appendix A.

### 2.2.1 Original Fuel Separations Facilities

Three large canyon buildings 221-T, 221-B and 221-U were originally constructed in the 200 Area in 1943 (?) to chemically separate plutonium from uranium and fission products. These buildings were massive rectangular canyons that housed the chemical separations equipment. This equipment was operated remotely to provide protection to the workers from the high radiation fields. The T Plant was started up Dec. 1944 and shutdown Aug. 1956 while B Plant started up in Apr. 1945 and shutdown in Oct. 1952. Since the capacity was not needed, the start up of U Plant was delayed until 1952 when the mission was changed (see section 2.2.4). The 221-T and 221-B buildings known as the T and B Plants utilized a bismuth phosphate precipitation batch process to separate plutonium from the uranium and fission products after the aluminum jackets were dissolved in sodium hydroxide solution and the uranium metal slugs were dissolved in nitric acid. The dilute plutonium solution from T and B plants was transferred to the 224 Concentration Buildings (e.g. 224-B and 224-T) located behind each canyon building where the product was purified, the product volume was reduced and the carrier was changed from bismuth phosphate to lanthanum fluoride. The final plutonium product was concentrated in the 231-Z Building. The B Plant was closed in 1952. Starting in 1954 and 1955, the processing capacity was increased in both facilities. The 221-B and 221-T plants were not restarted because of the success of PUREX.

In March 1956 221-T was converted to perform equipment decontamination (WHC-MR-0452). In 1959 the 2706 T Decon Annex was added to the 221-T building to enhance the equipment decontamination capabilities, particularly pieces of equipment too large to take into T-Plant. The T-Plant is still in operation.

The B Plant facilities were modified in 1968 to remove  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  from high-level wastes from the single and double-shell waste tanks. This was in support of a new mission "to isolate the longer-lived fission products by fractionalization for storage in a safer form and to return the short-lived fractions to underground storage and ultimate solidification". The purified  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  solutions were transferred to the 225-B Waste Encapsulation Storage Facility (see section 2.2.6). The 221-B operated from 1968 to 1978 in support of this new mission.

### **2.2.2      202-S REDOX Plant**

Construction of the REDOX Facility (S Plant) was started in 1949. In Jan. 1952, REDOX started up in the 200-W Area utilizing the REDOX (i.e. reduction/oxidation process) as a replacement for the bismuth phosphate process. This new REDOX process differed from the process used in B and T Plants in that with the exception of the metal dissolving and feed preparation steps, all steps were continuous rather than batch. The new process, which involves solvent extraction utilizing hexone, resulted in improved throughput, recovery of uranium, improved recovery of plutonium and a decrease in the amount of high-level liquid waste generated. The aqueous plutonium product was concentrated for shipment to the plutonium finishing facilities. In 1950\* processing of irradiated 94 metals (0.947 enrichment) was assigned to REDOX. Shutdown of this facility occurred in Dec. 1967.

In an effort to enhance production capacity, the 233-S building was constructed in 1957 to contain the third and final concentration cycle at 202-S. This building was shut down in July 1967 after a major fire resulted in extensive plutonium contamination. The facility is currently undergoing decontamination and decommissioning.

### **2.2.3      202-A PUREX Plant**

Construction of the PUREX Facility (A Plant) commenced in 1953. It was started up in Jan. 1956 utilizing the plutonium-uranium extraction process (WHC-MR-0437: Marceau, 2002). The PUREX process was an organic solvent extraction process that utilizes tributyl phosphate in kerosene instead of hexone, nitric acid as a salting agent, pulse column contractors, and nitric acid recovery by distillation. The nominal design capacity was 8.33 short tons uranium per day as opposed to 2.5 for the REDOX Plant. In 1955 due to the development of more restrictive <sup>131</sup>I release limits the 293-A facility was constructed between PUREX and the 291 A stack. In 1958 PUREX initiated <sup>237</sup>Np recovery activities. Equipment was added in 1962 to permit continuous recovery of <sup>237</sup>Np. In 1963 the processing of e-metal fuel containing <sup>235</sup>U enriched to 1.75 %. The processing of irradiated powdered thorium oxide targets to recover <sup>233</sup>U commenced in 1965 and 1966. In 1970 the targets were changed to pelletized thorium oxide. The PUREX Plant was shutdown in June 1972 and restarted in Nov. 1983. During the shutdown a new process was added to convert plutonium nitrate to plutonium oxide. It was started-up and shutdown several times between 1983 and 1992 with final closure announced in Dec. 1992.

A 500-foot railroad tunnel that extended south from PUREX was designed and constructed to permit the remote storage of highly contaminated processing equipment. In 1964 a new 1500-foot tunnel was added to PUREX to accommodate the storage of additional equipment.

### **2.2.4      221-U U Plant**

As noted in section 2.2.1 above, the U Plant was constructed in 1943. The U Plant startup was delayed until Mar. 1952 when it was reconfigured for use in recovering uranium from process waste. The high-level liquid wastes from the B and T Plants, which were stored in single-shell tanks, contained large quantities of uranium. The uranium bearing sludge from the underground storage tanks was pumped to process vessels in the U Plant. The sludge was dissolved in nitric acid and the uranium extracted by solvent extraction using tributyl phosphate in kerosene. The recovered Uranium was shipped off-site for reuse. The U Plant was shutdown in Jan. 1958.

### **2.2.5 224-U UO<sub>3</sub> Plant**

The 224-U Bulk Reduction Building (known as UO<sub>3</sub> Plant) was constructed in the 1940's. In 1951 it was converted to process the liquid uranium nitrate solution from U Plant to produce a powdered uranium oxide (UO<sub>3</sub>) using a calcination process. It was started up in Jan. 1952. The product was shipped off-site for reuse. A major addition (224 UA) was added to the UO<sub>3</sub> Plant in the fourth quarter 1956 to house 3 new calciners. It was shutdown in 1972 and opened again in 1983 (there were 17 start ups and shutdowns between 1984 and 1992 corresponding to activities at PUREX) and was deactivated in the summer of 1993.

### **2.2.6 225 Waste Encapsulation and Storage Facility**

The 225-B Waste Encapsulation and Storage Facility is located in the 200-E Area near the 221-B Building. In 1979\* as a part of the effort to "isolate the longer-lived fission products from high-level waste tanks the <sup>137</sup>Cs and <sup>90</sup>Sr solutions were transferred to the 225-B from 221-B for conversion to a solid, encapsulation, and storage (see section 2.2.1 for more details). A large amount of encapsulated <sup>137</sup>Cs and <sup>90</sup>Sr was stored in the 225 Building as a result of this operation. External exposures that were associated with the high- energy photons and beta particles from the large quantities of strontium and cesium processed were minimized as a result of remote operation. Internal exposures from the operation were minimal due to the remote operation.

### **2.2.7 201-C C Plant or Hot Semiworks**

The Hot Semiworks (also known as hot sloppy) started up in 1949 as a pilot plant (Marceau, 2002) to develop REDOX reprocessing technologies. The REDOX process was tested in the 201-C reprocessing pilot plant starting in 1952, with work continuing until 1954. In 1954, the C Plant was switched to being the PUREX process pilot plant and was shutdown in 1956. In 1962, C Plant was restarted as a pilot plant for the recovery of Cs and Sr from fission product waste. The C Plant was retired in 1967.

### **2.2.8 108-B Tritium Extraction Facility**

The 108-B building (known as P-10 Plant and also the Mint Works) located in the 100-B Area started in Aug. 1944 to extract tritium. The Li-Al (for a short period lithium fluoride) target elements were transferred to the 108-B facility after irradiation in one of the production reactors. Tritium extraction operations were performed intermittently between Aug. 1949 and 1955. The 108-B tritium operation was terminated in 1955. The Li-Al target irradiation was continued with transportation to an offsite facility for processing until Sep, 1964. A total of 10.6 kg of tritium was produced at Hanford. Internal exposure was related to tritium (<sup>3</sup>H). This whole body exposure was added to whole body dose summary (See sections 5 and 6 - External and Internal Dosimetry).

## **2.3 FUEL FABRICATION FACILITIES**

The Hanford Fuel Fabrication facilities described in subsequent sections were built and operated in the 300 Area from 1944 to 1988. These include three fuel fabrication facilities, 313 (Uranium Metal Fuels Fabrication), 314 (Uranium Metal Extrusion), and 333 (Fuel Cladding) buildings, and two support facilities, 303 (Uranium Storage and Oxide Burner), and 306 (Reactor Fuel Manufacturing Pilot Plant). External exposures were related to betas and photons associated with uranium. Due to the pyrophoric nature of uranium turnings and chips, internal exposure was related primarily to inhalation of uranium. The years of operation and radionuclides are shown in Tables A.3-1 and A.3-2 respectively in Appendix A.

### **2.3.1 313 Uranium Metal Fuels Fabrication Facility**

The aluminum-clad fuel for the first eight production reactors was produced in the 313 Building starting in Mar. 1944 (*Key dates doc says Dec. 1943*). Natural uranium billets or bars were heated to a red heat and shaped into long rods using an extrusion press (see 314 building below). These were cut into shorter lengths called slugs using a turret lathe. After receiving a finish cut in another turret lathe, the slugs were degreased using nitric acid. The cleaned slugs were dipped in a succession of molten baths (i.e. triple-dip method) and pushed into an aluminum can. An aluminum cap was pushed into the can and the top edge of the cap was welded to the can. Bismuth fuel targets were fabricated in the 313 Building beginning in 1944. These were irradiated in the production reactors to produce  $^{210}\text{Po}$  (used as an initiator in the earliest atomic weapons). Lead-cadmium fuel rods, welded into non-bonded aluminum cans, were produced for use as "poison" elements for the production reactors. Lithium targets were manufactured for tritium production from 1949 to 1952 and again from 1965 to 1967. In the 1950's, production reactor fuel changed from natural uranium to low enriched uranium (LEU). In Mar. 1954 a new, simpler, canning method involving a lead-dip process was initiated to replace the old method. All uranium scrap and waste from these processes was salvaged as uranium oxide and shipped off the Hanford site. In 1955 the fuel production facilities were expanded to produce the fuel for the K Reactors. In Jan. 1971 the manufacture of aluminum-clad fuel used in the first six reactors was terminated. After that time, only N-Reactor fuel was manufactured (see section 2.3.3 below).

### **2.3.2 314 Uranium Metal Extrusion Facility**

The 314 building was known as the Press Building, Metallurgical Engineering Laboratory and later as the Uranium Metal Extrusion Facility. Operation of the 314 Press Building was commenced in July 1944 with a mission to process raw uranium billets into extruded rods that were suitable for fabrication into fuel elements. In early 1945, a 1000-ton large extrusion press was installed in the 314 building. After installation, the 313 and 314 buildings assumed all of the fuel manufacturing responsibilities for Hanford. An additional mission, uranium scrap recovery, was started in 1945. An oxide burner was operated outside the building in 1946. A melt plant started operation in December 1947. Uranium scraps were mixed with  $\text{UF}_4$  (green salt) and calcium chips. Conversion to metal took place in a reduction furnace (HS300AHD). The high air contamination that occurred frequently, involved a highly soluble, class F material. The melt plant was shut down in 1954. The uranium billets were extruded into rods, outgassed and straightened in the 314 building. The extrusion process was terminated in 1948 the fuel element process was changed to use rolled uranium rods. An oxide-burner was installed in the 314 building in 1946. In 1950, a rolling mill was installed in the 314 building in order to fabricate Hanford fuel elements on site. The building was deactivated in 1971.

### **2.3.3 333 Fuel Cladding Facility**

The N Reactor fuel was produced in the 333 building starting in 1961. The N Reactor fuel elements used a tube-in-tube design consisting of slightly enriched uranium inner and outer cores and thin zircaloy-2 cladding. The production process included: cleaning of the uranium billets and Zirconium-2 cladding shells; billet assembly and preheating; extrusion; fuel element shaping and cleaning; and welding of the end cap. In 1965 -1967 outer driver fuel elements were produced in support of tritium production at N Reactor. The Li/Al inner target element was manufactured in the 3722 Area Shop. The 333 building was placed on standby in 1988 when the manufacture of N Reactor fuels ceased.

#### **2.3.4 306 Reactor Fuel Manufacturing Pilot Plant**

Construction on the 306 building was completed in 1956 and it began operation in May 1957 as a pilot plant for reactor fuel production. The 306 building had a complete fuel element canning line with the exception of autoclaving. The co-extrusion process was developed in the 306-E building in the early 1960's in support of the N Reactor fuel needs. This facility was shut down in 1984\*.

#### **2.3.5 303 Facilities Fresh Metal Storage Facilities**

Ten buildings (303-A, B, C, D, E, F, G, J, K, and M) were built over a period of years from 1944 to 1983 to store fresh uranium, chemicals, uranium scraps and plutonium. Uranium was shipped to Hanford in the form of metal billets. The metal billets were moved to the 303 Fresh Metal Storage buildings where they were inspected, entered into accountability records and held for processing. The 303-J building was built in 1961 to house a uranium oxide burner and was shutdown in 1971 because of ventilation problems. In 1983, the new Oxide Burning Facility (303-M) was placed into operation at the same site. It operated from 1984 to 1987. In 1970\*, the 303-C building was utilized by PNNL for the storage of plutonium and americium. A pressurization of one of the sealed metal storage cans resulted in the spread of plutonium contamination and the subsequent shut down of the building until cleanup. It currently is being used for other purposes.

### **2.4 PLUTONIUM FINISHING FACILITIES**

Two plutonium finishing facilities, 231-Z (Plutonium Isolation Building) and 234-5Z (Plutonium Finishing Plant Complex) operated at Hanford from 1945 to present. The latter is still involved in plutonium stabilization efforts as a part of the Hanford cleanup program. Both of these complexes are located in the 200-W Area. As noted in section 2.4.3 below, the Plutonium Finishing Plant Complex consists of several buildings including: the 234-5Z that involves several processes (i.e. Rubber Glove line, Remote Mechanical A line, Remote Mechanical C line, and RECUPLEX); the 232-Z Incinerator; the 236-Z Plutonium Reclamation Facility; and the 242-Z Waste storage Facility. External exposures were related to radiation fields primarily from plutonium low-energy x-rays and spontaneous fission neutrons. During the early years of plutonium finishing operations, essentially all photon radiation resulted from plutonium x-rays. Later, 60 keV gamma radiation from <sup>241</sup>Am contributed significantly to worker exposure. Neutron radiation was substantially elevated in part of the finishing operation where alpha radiation from plutonium produced neutrons as a result of the  $\alpha/\eta$  reaction with fluorine. Although relatively few Hanford personnel were involved in plutonium finishing, these facilities provided the majority of personnel exposures to neutron radiation. Internal exposures were related to contamination incidents involving americium and plutonium. These exposures occurred by inhalation, absorption and injection (i.e. wound sites). The years of operation and the radionuclides of concern are listed in Tables A.4-1 and A.4-2 respectively in Appendix A.

#### **2.4.1 231-Z Plutonium Isolation Facility**

The 231-Z, Plutonium Isolation Facility began the plutonium finishing process in Jan. 1945 when the first plutonium nitrate solution was received. Adding hydrogen peroxide to separate the plutonium from the nitrate solution purified plutonium. Until July 1949 the plutonium was dried and shipped offsite for further refining. When the 234-5Z (see Table A.4-1) went into operation, in July 1949, the refined product was shipped offsite for plutonium finishing. Chemical processing was continued in the 231-Z building until 1956 when all steps were transferred to the 234-5Z building. In 1956 the plutonium metallurgy developmental laboratory was moved from 234-5Z to 231-Z. The 231-Z building continued to be used for metallurgical research on plutonium and alloys until 19UNK. Studies on the use of U-233 were also performed in this building.

1 Table 2.4.1-1. Plutonium nitrate processing tasks.

Task	Name	Function
I	Purification, Oxalate Precipitation, Wet Chemistry, or Feed Production	Precipitate the plutonium-nitrate feed solution with Oxalic acid and other agents;
II	Hydrofluorination or Dry Chemistry	Diffuse hydrogen fluoride gas through the precipitate;
III	Reduction	Combine the plutonium tetrafluoride with calcium; Fire at high temperature until fused into a metallic plutonium chunk called a button;
IV	Casting	Render plutonium buttons into pits;
V	Machining	Machine the pit to specified dimensions;
VI	Cleaning	Chemically clean the pit;
VII	Coating	Coat the pit for radiation safety; and
VIII	Final Inspection	Inspect the pit for correct specifications.

2

### 3 2.4.2 234-5Z Plutonium Finishing Plant Complex

4 The 234-5Z building was used starting in July 1949 for plutonium finishing operations. The Plutonium  
5 Finishing Plant (PFP) Complex consists of the 234-5Z building including several production areas and  
6 several other buildings discussed in subsequent sections. The building is currently under going D &  
7 D.

#### 8 2.4.2.1 Rubber Glove Line

9 The Rubber Glove (RG) Line in the 234-5Z building was used starting in July 1949 for processing  
10 plutonium nitrate. All of the tasks listed in the following table with the exception of task 1 were  
11 performed in the RG line.

12 In Dec. 1949, production was temporarily halted to make repairs to solve operational and mechanical  
13 problems. It was restarted early in 1950. The RG line was placed on standby at the end of Mar. 1953  
14 with the exception of the coatings units that were shutdown in May 1953. In 1955, equipment from  
15 Tasks I and II was removed and buried. A majority of the remaining process equipment was removed  
16 from the RG line in early 1957 in preparation for installation of the new RMC line.

#### 17 2.4.2.2 Remote Mechanical A Line

18 The Remote Mechanical A Line (RMA) was designed to reduce worker radiation exposure by  
19 automating the process described in the above table. In Mar. 1952, the RMA line began to process  
20 the plutonium (IV) oxalate that was prepared in 231-Z. By Mar. 1953 the RMA line began handling all  
21 of the plutonium work. In July 1954 a fire in the RMA line stopped fabrication of pits for three weeks.  
22 The RMA line was taken completely out of service in 1964. The weapon fabrication portion of the  
23 RMA line was removed (see RMC line below) in Mar. 1966. In Sept. 1967, a glove box in the RMA  
24 line was reactivated in order to grind plutonium-aluminum scraps into turnings suitable for plutonium  
25 recovery. In 1968, Tasks I-III of the RMA line were cleaned out and reactivated to participate in  
26 expanded programs for commercial (i.e. non-defense) nuclear development and experiments such as  
27 oxides for the Hanford Fast Flux Test Facility. In 1984, it was decided to keep the RMA line in  
28 standby status. It was never operated again.

#### 29 2.4.2.3 Remote Mechanical C Line

30 The Remote Mechanical C Line (RMC) began processing plutonium nitrate feed in Oct. 1960. In 1962  
31 a project was undertaken to install ten-inch thick water-filled shielding tanks to substantially reduce

the neutron exposure to operators. Because of fire(s) in other facilities and the RECUPLEX criticality, other safety improvements including a new criticality alarm system, a new air sample counter and a new paging system were installed in 1963 and 1964. By 1964 the RMC line was being used for a bulk of the metal processing and the throughput was increased substantially. As a result of a decision to concentrate weapon fabrication work at Rocky Flats, the fabrication portion of the RMC line was removed in Mar. 1966. The line continued to operate on a mixed schedule for the next several years producing weapons-grade plutonium and fuel-grade plutonium and oxides. As a result of the explosion in the americium recovery process in the 242-Z facility, the RMC line was shutdown in 1976. After preparing to restart production of weapons-grade components, the RMC Line restarted in July 1985. The RMC line was permanently shut down in May 1989.

#### **2.4.2.4 Recovery of Uranium and Plutonium by Extraction Facility**

The Recovery of Uranium and Plutonium by Extraction (RECUPLEX) process facility began in July 1955, over the next few years; the facility was heavily used with increasing equipment failures and increasing radiation levels. In Feb. 1960, RECUPLEX was temporarily shut down to permit an extensive cleanup of hoods and operating equipment. In Apr. 1962, a criticality accident resulted in widespread contamination throughout the RECUPLEX room and in high external exposures to several workers. In May 1962 the Atomic Energy Commission decided to deactivate that section of the 234-5Z facility.

#### **2.4.2.5 232-Z Incinerator Facility**

In Jan. 1962, the 232-Z Incinerator began processing miscellaneous solid wastes to recover small quantities of plutonium. The process involved incineration of combustible materials, leaching non-combustible materials in nitric acid and wet leaching of ash. The recovered plutonium was transferred to RECUPLEX and later the Plutonium Reclamation Facility. In 1973 the 232-Z incinerator was shut down.

#### **2.4.3.6 236-Z Plutonium Reclamation Facility**

The 236-Z Plutonium Reclamation Facility (PRF) was placed into operation in May 1964 to recover plutonium from liquid waste generated in the plutonium finishing plant operations. Using a solution of tributyl phosphate diluted with carbon tetrachloride, metal nitrates and other wastes were stripped from a plutonium bearing feed. Nitric acid-hydroxylamine solution was then used to separate the plutonium as a nitrate. The plutonium nitrate was then ready as a feed for the RMA and RMC lines. In Dec. 1975, 236-Z was shut down for maintenance upgrades and reviews of criticality safety specifications and procedures. In 1976 the 236-Z operated for only a short time after restart until the explosion in 242-Z resulted in widespread, high levels of <sup>241</sup>Am contamination in the work area. This accident resulted in the shutdown of the entire Plutonium Finishing Complex in April 1976. Any internal exposures would be the result of an accident.

#### **2.4.2.6 236-Z Plutonium Reclamation Facility**

The 236-Z Plutonium Reclamation Facility (PRF) was placed into operation in May 1964 to recover plutonium from liquid waste generated in the plutonium finishing plant operations. Using a solution of tributyl phosphate diluted with carbon tetrachloride, metal nitrates and other wastes were stripped from a plutonium bearing feed. Nitric acid-hydroxylamine solution was then used to separate the plutonium as a nitrate. The plutonium nitrate was then ready as a feed for the RMA and RMC lines. In Dec. 1975, 236-Z was shut down for maintenance upgrades and reviews of criticality safety specifications and procedures. In 1976 the 236-Z operated for only a short time after restart until the explosion in 242-Z resulted in widespread, high levels of <sup>241</sup>Am contamination in the work area. This accident resulted in the shutdown of the entire Plutonium Finishing Complex in April 1976.



#### **2.4.2.7 242-Z Waste Treatment Facility**

The 242-Z Waste Treatment Facility began operation in 1963 to recover plutonium from aqueous waste streams from the PFP. An americium-241 recovery process was installed in a glove box in 242-Z and began operation in May 1965. The recovery process was converted from a batch to a continuous process in 1969. In April 1976, the 242-Z facility was shut down as a result of a strike. In August 1976 during restart of the americium recovery process, an explosion occurred in a cation ion exchange column containing approximately 100 grams of americium-241. This resulted in substantial Americium internal exposure. As a result, the 242-Z facility was permanently closed. Doors into the operating area were welded shut and the facility currently is waiting D&D efforts.

#### **2.4.3 Plutonium Storage Facilities**

Several plutonium storage facilities were constructed at the PFP (234-5Z) starting in 1949. These include: 2736-Z, 2736-ZA, and 2736-ZB built in 1971, 1977, and 1982 respectively. There were 12 vault or vault-type rooms in the PFP. These vaults contained 93 percent of the Hanford Site's unirradiated plutonium items and 92 percent of the total Hanford unirradiated plutonium inventory in July 1994 at the time the Plutonium Vulnerability Study (DOE, 1994) was performed. External exposure in the vault rooms from low-energy photons and neutrons occurred during periodic inventory and inspection activities. Internal exposure was minimal since there were no routine activities that involved opening the storage containers. Internal exposure would have been a concern in the event of an incident that voided the containment afforded by the storage containers. Stabilization efforts were completed in Aug. 2003.

### **2.5 RESEARCH, DEVELOPMENT, AND TESTING FACILITIES**

The 21-major Research, Development, and Testing Facilities at Hanford were located in the 100, 200 and 300 Areas. Construction of these started in 1944 with the last one completed in 1977. These facilities were built to support the development and testing of new processes, materials, and equipment. In some instances the facilities were used for several different purposes throughout their operating life. Therefore, the potential exposures are dependent on the processes involved and the mission/process at any given time. The years of operation and the radionuclides of concern are listed in Tables A.5-1, A.5-2 and A.5-3 in Appendix A.

#### **2.5.1 108-F Biology Facility**

The 108-F building was remodeled in 1949 to provide laboratory and office space for the Hanford Site Biology Program. The facility was used to perform radiation effects studies on plants, animals and fish in support of Hanford plant operations. Studies involved many radionuclides including <sup>90</sup>Sr, <sup>131</sup>I, <sup>238</sup>U, and <sup>239</sup>Pu. The building was expanded in 1953 and again in 1962 to provide additional space for biological experiments. The facility was closed in 1977 when the Biology Program moved to the 331 building (see section 2.5.16 below).

#### **2.5.2 120 Critical Mass Laboratory Facility**

The Critical Mass Laboratory was originally operated in the 120 building located near the 100-F Area starting in Apr. 1950. This laboratory was used for nuclear physics R&D studies of plutonium solutions and solids to avoid the accidental occurrence of a criticality event in an operating facility. In Nov. 1951, a substantial spread of contamination occurred as a result of an experiment performed with a plutonium solution. In Dec. 1950, spontaneous ignition of rags soaked with nitric acid occurred during cleanup. While the metal building was not destroyed, the facility was permanently closed due

to the extensive plutonium contamination. The site was subsequently decontaminated and decommissioned.

### **2.5.3      209-E Critical Mass Laboratory**

The 209-E Critical Mass Laboratory was placed into operation in July 1961. The laboratory, located in a room shielded by at least 3 ft of concrete, included a mixing room with a glove box and mixing hood and a control room from which critical mass physics experiments were remotely conducted. Both <sup>239</sup>Pu and <sup>240</sup>Pu was used in the criticality studies. As a result external exposures were minimized. Internal exposures were related to contamination incidents involving plutonium. This facility was shut down in 1986\* after a series of occurrences involving criticality safety specifications.

### **2.5.4      222-B Laboratory**

The 222-B laboratory was opened in the 222-B building in 1945 to perform process or research and development radiochemical operations in support of irradiated fuel-reprocessing facilities. One of the main functions was to test the solution samples from the 221-B and 224-B buildings at various steps in the separations process. External and internal exposures were associated with the FP and plutonium in the process samples. It was shutdown in ~1975. This facility was converted to office space.

### **2.5.5      222-S Laboratory**

Construction of the 222-S laboratory was started in 1949. The laboratory contains laboratories and shielded cells that were used to provide analytical services in support of process control of REDOX, B-Plant and 242-S and 242-A Evaporators. It currently is used for analytical operations in support of waste management and environmental control processes. External exposures were related primarily to FP in process samples. Internal exposures would primarily be associated with samples associated with the separations plants process samples (e.g. FP and plutonium). In the early 1960's, some work was performed with <sup>147</sup>Pm. Internal exposures were primarily related to contamination incidents.

### **2.5.6      222-T Laboratory**

The 222-T Laboratory was the first to operate commencing in 1944 in support of the separation process in 221-T and supporting work in 224-T. External and internal exposure potential was similar to that in 222-B above. It was shutdown in 1980\*. Fire protection was shutoff in 1986.

### **2.5.7      308 Plutonium Fuels Pilot Plant**

The Plutonium Fuels Pilot Plant (PFPP) was constructed in the 308 building in 1960 to perform research and development on fuel elements used in the PRTR. In the mid 1960's the PRTR fuel work was terminated. In the late 60's, neptunium-aluminum alloy fuel target elements were produced for use in N Reactor for a Pu-238 production run. A high bay area was added to the building in 1971. A <sup>147</sup>Pm contamination incident occurred in the 308 building in 1971. From 1977 to 1991 the facility was used for the production of FFTF fuel elements. The 308-A annex was added to the Plutonium Fabrication Pilot Plant in 1979 to accommodate additional plutonium fuels work. A 250 kW Training Research Isotopes, General Atomics (TRIGA) reactor was installed in the annex in the late 1970's to perform neutron radiography, a feature of the QA testing program. During its operation, the building experienced many incidents involving the loss of control of radioactive materials, primarily plutonium. Most of these were contained within usually one laboratory and in adjacent corridors. Glove box fires, explosions, and/or ruptures were the most frequent cause of contamination. Improperly sealed

irradiated sample containers were another common cause. These incidents occasionally resulted in internal exposures. The 308 facilities were deactivated in 1990\*.

### **2.5.8      318 Radiological Calibration and Development Laboratory**

The 318 building was originally built in 1967 to house the HTLTR reactor (see section 2.1.8). In the early 1980's, the reactor was removed and the heavily shielded 10-meter cube reactor cell was converted to a free-in-air calibration facility that contains a large  $^{252}\text{Cf}$  neutron source ( $10^9$  n/s) and a large  $^{137}\text{Cs}$  photon source (~100 Ci) that were used for dosimeter calibration. A shielded facility was built in the basement to house a high-level  $^{60}\text{Co}$  source (~1kCi) to create accident dose rate levels and three 300 kVp X-ray machines. The calibration laboratory commenced operation in 1983. Three major additions were constructed in 1985, 1987 and 1989. The first contained four source wells that held two  $^{137}\text{Cs}$ , one  $^{60}\text{Co}$ , and one  $^{252}\text{Cf}$  sources used for instrument calibration. The second addition houses instrument testing and repair laboratories and the last addition provided office facilities for the staff. As a result of the shielding, isolation, remote operations, and operating procedures, external exposures were minimized. Internal exposures were negligible. The facility is still in operation.

### **2.5.9      320 Low-Level Radiochemistry Facility**

The Low-Level Radiochemistry Laboratory was built in the 320 building in 1966. The original mission was to house analytical chemistry services and provide plant support involving low-level and non-radioactive samples. The 320 Building currently provides a low-level radiochemistry facility in which very sensitive radiochemical analysis, sample preparation, and methods development can be performed. External and Internal exposures were minimal. The facility is still in operation.

### **2.5.10     321 Separation Facility**

The 321 Separation Facility (Cold Semi-Works) was built in 1944 with a mission to be used as a cold (i.e. non-irradiated material) pilot plant to test the bismuth phosphate chemical reprocessing methods and equipment and to study problems as the 221, 224, and 231 buildings were being constructed. In late 1944, it was decided to add a laboratory for work with small amounts of solutions containing several tenths of a curie to a curie of radioactive materials (Gerber, 1993; HS300AHD). Soon after start-up, the 321 building assumed a mission to demonstrate the effects of proposed process changes on decontamination factors in the 221, 224, and 231 buildings, conducting isotope separations, and experiments on small-irradiated samples. In 1949 321 was used to develop the REDOX process. Tests using radioactive materials were discontinued after 1949. The 321 building was used in 1953 to perform a cold test of the PUREX process. Pilot scale tests of the U-Plant recovery process were conducted in 1955. Isotope Campaigns were conducted in the 1960's using tracer-levels of  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ ,  $^{144}\text{Ce}$ ,  $^{147}\text{Pm}$ , and  $^{237}\text{Np}$ . Primary contamination in the facility was due to thorium and uranium. External and Internal exposures were minimal. The building was deactivated in 1988.

### **2.5.11     324 Chemical and Materials Engineering Laboratory**

The Chemical and Materials Engineering Laboratory began operation in 1966 to provide research and development studies in support of the PRTR operations. It was used first as a fuel recycle pilot plant by housing chemical reprocessing and metallurgical examination capabilities used for PRTR fuel elements. It consisted of two groups of large shielded cells used for both radiochemical and metallurgical studies. The chemistry cells consisted of four cells connected to an air lock where studies of various processes for solidifying high-level liquid waste were performed. It was used in conjunction with the 325-A hot cells to perform studies on solidification of high-level liquid waste (i.e. Nuclear Waste Vitrification Project) from processing irradiated fuel elements from commercial

reactors). A special underground liquid waste pipe line connected the hot cells in 324 and 325-A. Most recently, it was used as a Waste Technology-Engineering Laboratory. Since most of the work was performed in hot cells, external and internal exposures were minimized. The 324 building is currently undergoing decontamination and decommissioning activities.

#### **2.5.12     325 Radiochemistry Laboratory**

The 325 building was completed in 1953 to permit multi-curie level chemical development work in support of production and process improvement (Marceau, 2002; HS300AHD). A high-level radiochemistry wing, 325-A, was placed into operation on the east side of the building in 1959/1960. It included three large hot cells for isotope research activities. This included separation and concentration of  $^{90}\text{Sr}$ ,  $^{90}\text{Y}$ ,  $^{131}\text{I}$ ,  $^{137}\text{Cs}$ ,  $^{144}\text{Ce}$ ,  $^{147}\text{Pm}$ ,  $^{210}\text{Po}$ ,  $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ , and  $^{244}\text{Cm}$  for special programs. The  $^{147}\text{Pm}$  was used in the manufacture of heat sources starting in 1966. The  $^{210}\text{Po}$  work started in June 1972 and was terminated in 1970\*. In 1990\*,  $^{90}\text{Y}$  was separated from  $^{90}\text{Sr}$  in multi-Curie quantities for medical use. These cells were also used in support of the studies on solidification of high-level radioactive waste (i.e. Nuclear Waste Vitrification Project) from processing irradiated fuel elements from commercial reactors. A special underground liquid waste pipe line connected the hot cells in 324 and 325-A. The Nuclear Waste Vitrification Project that was conducted in the 324 and 325 buildings in the 1970's, involved high "burnup" commercial fuel elements were characterized by nominally 26%  $^{240}\text{Pu}$  (Carbaugh 2003). High-level radio-analytical hot cells were added on the west side in 19UNK. The building became known as the Radiochemistry/Cerium recovery Building. Limiting access to high-level dose-rate or contamination areas controlled external and internal exposures. Most exposures were related to maintenance performed in hot cells or accidents in laboratory areas where work was being performed with FP, plutonium, and other radionuclides. A major  $^{147}\text{Pm}$  contamination incident occurred in the late 1960's. The radiochemical laboratory work resulted in external exposure and any internal exposure resulted from contamination incidents. The 325 building still is in use in support of cleanup efforts at Hanford.

#### **2.5.13     326 Pile Physics Technology and Metallurgy Facility**

Operation of the 326 building started in 1953 to continue exponential pile physics development work originally performed in the P-11 Facility and later in 189-D (Marceau, 2002; HS300AHD). Po-Be and Ra-Be neutron sources with neutron emissions up to  $1 \times 10^8$  n/s were used to irradiate Co and Cu test foils. The test foils exhibited radiation levels up to 10 rad/h at 3 inches. The facility was also used for metallurgical studies of reactor components and fuel elements to evaluate characteristics and performance. Some of this work was transferred to 209 E in 1961. A High Energy Electron Microscope was installed in the basement in 1971 to perform materials studies. During microscope operations, there was a major spread of plutonium and irradiated steel (i.e. Fe) contamination. This and other contamination incidents resulted in some internal exposure. In 1983 the 326 building became the "Chemical Science Building". This facility is still in operation.

#### **2.5.14     327 Radiometallurgy Laboratory Facility**

The 327 Radiometallurgy Laboratory was built in 1953(?) to replace the 111-B Test Building (Gerber, 1993; Marceau, 2002; HS300AHD). It was designed to provide for post testing and other studies on irradiated materials, particularly fuel elements and fuel cladding materials from and for the production reactors. These facilities originally consisted of eight free standing shielded cells and two water-filled storage pools. Several modifications were undertaken to provide a shielded load out facility to handle high-level radioactive waste, a large shielded cell to perform special environmental Radiometallurgy studies and office space. In 1967 it was used for the experimental production of Pu-238. It was used to study irradiated PRTR, FFTF, GETR, EBR II and MTR fuel elements. In 1967 it was involved in a

serious contamination event. The 327 building was renamed the Post Irradiation Testing Laboratory in the 1980's. External and internal exposures were related to irradiated materials, and FP that were undergoing metallurgical studies. Work was also performed with  $^{233}\text{U}$  and  $^{238}\text{Pu}$ . The facility was deactivated in 1987.

#### **2.5.15 329 Biophysics Laboratory**

The biophysics laboratory was opened in 1952 to pioneer development of water chemistry, environmental monitoring, and bioassay analysis programs. Missions for the Laboratory include the analyses of low-level (i.e. near background) quantities of radioactive materials in air, vegetation, soil, wildlife, river and well water samples. A neutron multiplier facility was built in 1974 as section D of the biophysics laboratory. It commenced operation in 1977 with a large  $^{252}\text{Cf}$  source. External and internal exposures were minimized. The building is still in operation.

#### **2.5.16 331 Life Sciences Laboratory Facility**

The Life Sciences Laboratory opened in the 331 building in 1972 as a replacement to the 108-F complex. The facility was used to perform radiation effects studies on plants, animals and fish in support of Hanford plant operations. Studies involved many radionuclides including  $^{90}\text{Sr}$ ,  $^{131}\text{I}$ ,  $^{238}\text{U}$ , and  $^{239}\text{Pu}$ . A hot cell that originally contained a 15 kCi  $^{60}\text{Co}$  source was used for special irradiation studies. External and internal exposures were a minimum. The facility is still in operation.

#### **2.5.17 3706 Radiochemistry Laboratory**

The 3706 building, the original radiochemistry laboratory was placed in operation in early 1945 (Gerber, 1993; Marceau, 2002; HS300AHD). This building was also known as the Technical Building. The original mission was to perform small-scale experiments with both low- and high-activity radioactive materials in support of production activities with the primary focus on improving the bismuth phosphate process. The QA/QC activities associated with fuel element fabrication also were performed in 3706 building. Another mission was the metallurgical examination of irradiated fuel elements, fuel development for the 313 Building, examination of graphite from the experimental levels of the 100 Area piles and special sample analyses from 231Z and 200 Area separation facilities. In 1947, it was used in the development of the REDOX process. Pioneering radiochemistry work in the development of the REDOX, PUREX, and RECUPLEX processes was performed until 1953. Work involved many radionuclides including FP,  $^{14}\text{C}$ ,  $^{131}\text{I}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ , and  $^{239}\text{Pu}$ . External and internal exposures were related to these radionuclides. Thyroid checks were initiated in May 1947. In 1954, many of the laboratories were decontaminated and converted to offices. During the 1970's and 1980's most of the remaining building was converted to offices and still were in use in the early 1990's.

#### **2.5.18 3730 Gamma Irradiation Facility**

The 3730 building was originally constructed in 1949 as a shop. In 1956 the work performed in the 3741 building was transferred to this building. A 350 kCi Co-60 source was added to a pool in the 1960's for special irradiation studies. Irradiated samples measured from 25 to 50 rad/h. Respiratory protection was required in the 1950's because of  $^{14}\text{C}$  and  $^{35}\text{S}$  airborne contamination. Several facility improvements were made during 1974 to 1981.

### **2.5.19     3732 Process Equipment Development Laboratory**

The 3732 Process Equipment Development Laboratory was constructed in 1949 as an engineering pilot plant for the triple-dip and lead-dip fuel canning processes (WHC-MR-0388). It is a one-story, metal frame structure seated on a concrete foundation, with a concrete floor and a corrugated metal roof. Overall dimensions are 28.5 ft by 48.16 ft. Powdered thorium oxide fuel targets for <sup>233</sup>U production were fabricated in the 3732 Building from 1965 to 1967. The process of handling these powder targets spread powdered and particulate thorium contamination throughout the building. After the thorium oxide program switched to pelletized targets in the 3722 Building in 1968, these new fuel targets were canned in the 3732 Building through 1970. As a result, the 3732 building contains standard fuel fabrication chemical wastes, as well as residual thorium oxide contamination in crevices and areas throughout and near the building. The facility is now empty.

### **2.5.20     3741 Graphite Hot Shop Facility**

The Graphite Hot Shop was constructed in 1944 to perform metallurgical studies on irradiated graphite samples. Po-Be and Ra-Be neutron sources were used in irradiation facilities in the basement to irradiate Co and Cu foils. Internal exposures would have been primarily due to the large quantities of irradiated graphite (i.e. <sup>14</sup>C) that were studied. The facility was torn down in 1956 and work was transferred to 3730 (HS300AHD).

### **2.5.21     3745 Radiological Calibrations and Standards Laboratory**

The Radiological Calibrations and Standards Laboratory was opened in the 3745 building in Oct. 1944. The two-story wooden frame building contained a low scatter room in which dosimeters were calibrated using a <sup>226</sup>Ra source and a 220 kVp X-ray machine. Other sources used included large <sup>60</sup>Co and <sup>137</sup>Cs photon sources and <sup>252</sup>Cf, <sup>226</sup>Ra-Be, <sup>84</sup>Po-B, <sup>84</sup>Po-Be, <sup>238</sup>Pu-Be, <sup>239</sup>Pu-F, and <sup>124</sup>Sb-Be neutron sources. Instrument calibrations were performed in a different room that contained two vertical concrete-shielded wells in which the photon sources were housed and used. Instrument calibration sources included <sup>60</sup>Co, <sup>137</sup>Cs, and <sup>226</sup>Ra sources. A supporting facility, 3745B, was constructed out of concrete blocks to house a 4 MeV Van de Graff positive ion accelerator. This was used starting in 1955 to perform fast neutron calibrations. A companion facility, 3745A, was built in 1950\* to house a 2 MeV negative ion Van de Graff accelerator. As a result of the shielding, isolation, remote operations, and operating procedures, external exposures were minimized. Internal exposures were negligible. The calibration operations were moved to the 318 building in 1983. The building is still used for office space.

## **2.6            WASTE HANDLING FACILITIES**

### **2.6.1        High-Level Liquid Waste Tanks**

High-level radioactive liquid wastes from reprocessing facilities at Hanford were stored in underground single-shell and double-shell tanks starting in 1944. The high-level radioactive waste is transported through underground process lines to the storage tanks that are located in tank farms in both 200-E and 200-W Areas. The storage tanks are of two types, single-shell and double-shell tanks. Both types are cylindrical shaped concrete structures with carbon steel liners. The single-shell tank has a single liner and the double-shell tank has two liners with a space in between. Initially, the T and B Plants produced over 10,000 gallons of high-level radioactive waste for each ton of uranium processed. These wastes were transferred to the first 64 tanks constructed in 1944-1945. Thirty new single-shell tanks were constructed in 1947-1948. Additional single-shell tanks were constructed in 1950-1952 (30), in 1953-1955 (21), and 1963-1964 (4). From 1968-1988 a total of 28 double-shell

tanks was constructed. Most of the single and double shell tanks are still in use. A new waste glassification facility is under construction to process the stored high-level liquid wastes. External exposure is due to high-energy beta and photon radiations from the fission products stored in the tanks. Under normal conditions shielding, distance and time, minimizes personnel exposures. Most external exposures would be related to leaks of high-level wastes. Internal exposures to FP were controlled through the use of respiratory protection.

#### **2.6.2      216-Z-9 Trench Facility**

The 216-Z-9 Facility known as the (Z-9) crib (i.e. enclosed trench) is located in the 200-W Area approximately 500 feet east of the Z Plant (i.e. PFP) exclusion area. The Z-9 trench was placed into operation in 1955 to serve the RECUPLEX Facility by receiving the acid waste stream of both aqueous and organic wastes as well as unwashed fabrication oil from the RMA line from 1955-1962. The trench was an underground excavation within an active floor area of 30 by 60 feet, 21 feet beneath the top of the concrete slab cover. The excavation was covered by a 9 to 12-inch thick reinforced concrete slab, 90 feet wide and 120 feet long at ground level. In 1965 because of concern that the waste plutonium posed a "potential criticality hazard" a decision was made to develop a soil mining and leaching operation to recover an estimated 45 kilograms of waste plutonium. A~1000 square foot containment structure was built underground to conduct the operation. It housed a soil packaging glove box, personnel entry to the trench, and a personnel change room. The structure was located on the east side of the trench with part of the structure located over the top of the trench cover. The mining operator's cubicle, which contained the controls for operating the mining equipment, was located within the west side of the trench cover through a reinforced opening in the trench cover. The mining operation commenced in Aug. 1976 and was completed in July 1978. The principal internal exposure potential was related to <sup>239</sup>Pu contamination, most of which occurred in the soil packaging glove box. Since the waste site was used only for plutonium, the external exposure potential during the mining operation was minimal. The facility currently is in a laid away status.

#### **2.6.3      241-Z Settling Tank**

The 241-Z Settling Tank, located within the fence of the PFP complex in the 200 West Area, was used from 1949-1973 to store large quantities of plutonium-bearing wastes. In 1974, 80,000 liters of supernate were removed from the tank leaving an estimated 94-inch deep layer of wet sludge containing a few tens of kilograms of plutonium. Internal and external exposures from this operation are minimal. The facility is currently awaiting D & D efforts.

#### **2.6.4      242 Evaporator Facilities**

The evaporator facilities (242-A, 242-B, 242-S and 242-T) were constructed near each of the separation facilities to reduce and concentrate the volume of high level wastes. The 242-T and 242-B Evaporators started processing high-level radioactive waste starting in 1951. Two new evaporator plants, 242-S and 242-A, commenced operation in 1973 and 1976, respectively. External exposure would be due to high-energy beta and photon radiations from the fission products stored in the tanks. Personnel exposures normally are controlled using shielding, distance and time. Most external exposures would be related to leaks of high-level wastes. Internal exposures to FP were controlled through the use of respiratory protection. The first three evaporator facilities were shut down in 19UNK. The 242-A is still in operation.

## 2.6.5 Chemical Separations Exhaust Filtration Facilities

Gaseous waste is grouped into three headings: dissolver off-gases, process vessel vent systems, and exhaust ventilation air. Dissolver off-gases contained the major portion of the radioactive iodine (primarily  $^{131}\text{I}$ ), as well as krypton and xenon isotopes. Dissolver off-gases also carried a high concentration of nitrogen oxides resulting from the reduction of nitric acid during the dissolution of the irradiated fuel elements. Table 2.6.5-1 shows the three exhaust filtration devices that were used starting in 1947 to reduce radioactive material releases from the B and T Separations Plants and later the REDOX Plant:

Table 2.6.5-1. Exhaust filtration facilities.

Filtration Devices	Date Installed
Caustic scrubbers	1947-1948
Sand filters and fiberglass filters	1947-1948 1954(REDOX)
Silver reactors	1950

These filtration devices accumulated substantive quantities of radioactive materials from the separations and plutonium concentrations. The caustic scrubbers were used to remove radio-chemical vapors from the process vessels. Sand filters were installed in the 202-S, 221-B, 221-T, 291-B, 291-S, 291-T, 291-Z facilities. The filters were used in exhaust streams associated with the separations process to remove particulates and to reduce ruthenium emissions from the exhaust stream. Silver reactors were installed primarily to remove  $^{131}\text{I}$  from the exhaust stream. Radionuclides of interest in the filtration devices include FP,  $^{103}\text{Ru}$ ,  $^{106}\text{Ru}$ ,  $^{131}\text{I}$ , and  $^{239}\text{Pu}$ . Internal and external exposures associated with these radionuclides would occur primarily during maintenance operations. These filtration devices became inactive as the separations facilities were shut down.

## 2.6.6 340, 340-A and 340-B Liquid Waste Handling Buildings

The 340-facility complex was operated starting in 1954 to receive radioactive liquid wastes from various 300 Area laboratories via the radioactive liquid waste sewer line. The complex accumulates the liquid wastes in storage tanks. After sample analyses and pH adjustment, the liquid wastes are shipped via a shielded railcar tank to the 200-E Area Tank Farms for treatment and disposal. The radionuclides of concern include:  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ ,  $^{90}\text{Y}$ ,  $^{137}\text{Cs}$ ,  $^{147}\text{Pm}$ ,  $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ , and  $^{144}\text{Ce}$ . Access to the tank area was administratively controlled. The external exposures to the operators were related to the high-energy betas and photons. Internal exposures were unplanned and would be related to leaks or an accident. The facility is still in use.



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**GLOSSARY****Burnup**

Depletion of fissionable material i.e.,  $^{235}\text{Pu}$

**Mint**

Tritium

**Pile**

Reactor

**Pit**

A machined part of a nuclear weapon

**Slugs**

Another name for fuel elements

## ATTACHMENT A – DESCRIPTION OF FACILITIES AND PROCESSES

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## A.1 REACTORS

External exposures at the Production Reactors are primarily due to presence of activation and fission products. During operation, entry was restricted or prevented into areas where high direct dose rates from photons and neutrons could occur.

Internal exposures at the Production Reactors are related primarily to the inhalation or absorption of activation products and, to a lesser degree, fission products during refueling and maintenance operations. Studies in later years at N-Reactor to characterize worker exposure indicated the primary internal exposure in the Production Reactors was due to  $^{60}\text{Co}$ , a corrosion product. It was stated (Sula, et al 1989), "In general, a major characteristic of these corrosion product radionuclides, regardless of origin, is the presence of several radionuclides within a matrix of oxidized metal with  $^{60}\text{Co}$  the predominant radionuclide". Several radionuclides in the metal oxide corrosion product mixture include:  $^{58}\text{Co}$ ,  $^{60}\text{Co}$ ,  $^{54}\text{Mn}$ , and  $^{59}\text{Fe}$  with  $^{60}\text{Co}$  being the predominant contributor to dose and activity. These radionuclides are all associated with elements found in steel and alloys used in reactor components. Other radionuclides may be present in trace amounts, but they generally are of minimal internal dosimetry significance.

There were seven small Research and Test reactors operated at Hanford starting in 1944 with only FFTF still in existence. Both external and internal exposures at these reactors were low (i.e. minimal in most cases) and unique to the specific reactor. With the exception of routine tritium exposures when working in the containment vessel at PRTR, external and internal exposures are primarily associated with minor accidents.

External exposure at the PRTR was minimized as a result of the remote operation and the shielding. Maintenance operations resulted in external exposure from activation and fission products. A high extremity exposure occurred when a worker picked up an irradiated steel pin. Tritium ( $^3\text{H}$ ) oxide was the principal internal exposure contaminant during normal operation. This was added into the whole body dose (see Internal and External Dosimetry Sections). The reactor was shut down in 1969 after an accident resulted in contamination in the reactor. A sample of the contamination showed the major contaminant was  $^{95}\text{Zr/Nb}$ . Other contaminants included  $^{60}\text{Co}$ ,  $^{103}\text{Ru}$ ,  $^{106}\text{Ru}$ ,  $^{106}\text{Rh}$ ,  $^{140}\text{Ba/La}$ ,  $^{141}\text{Ce}$ ,  $^{144}\text{Ce}$ , and  $^{144}\text{Pr}$ .

Table A.1-1. Production reactors years of operation.

Reactor								
B	C	D	Dr	F	H	KE	KW	N
9/1944- 2/1968	11/1952- 4/1969	12/1944- 6/1967	10/1950- 12/1964	2/1945- 6/1965	10/1949- 4/1965	2/1955- 1/1971	12/1954 -1970	12/1963- 1987

Table A.1-2. Radionuclides of concern for all production reactors.<sup>a</sup>

As-76	I-135	Sr-91
Ca-41	Mn-54	Sr-92
Co-58	Mn-56	U-238
Co-60	Na-24	Y-90
Cr-51	Nb-97	Y-92
Cu-64	Np-239	Y-93
Fe-59	P-32	Zn-65
Ga-72	Si-31	Zn-69
I-133		

a. The composition and relative abundance are not known. These radionuclides represent 98% of radioactive materials in effluents. It should be noted that several of these are short-lived activation products (e.g. <sup>31</sup>Si, <sup>76</sup>As, etc) that would result in only limited, if any, exposure to workers.

Table A.1-3. Research and test reactors years of operation.

Reactor						
HTR	PCTR	TTR	PRTR	PRCF	HTLTR	FFTF
1943- 1972	1954- 1970	1954-1978	1960- 1969	1962- 1976	1968- 1971	1980- 1994

Table A.1-4. Radionuclides of concern for all research and test reactors.

<sup>103</sup> Ru	<sup>235</sup> U	<sup>35</sup> S
<sup>106</sup> Rh	<sup>238</sup> Pu	<sup>210</sup> Po
<sup>106</sup> Ru	<sup>238</sup> U	<sup>226</sup> Ra
<sup>140</sup> Ba/La	<sup>239</sup> Pu	<sup>233</sup> U
<sup>141</sup> Ce	<sup>3</sup> H	<sup>237</sup> Np
<sup>144</sup> Ce	<sup>60</sup> Co	<sup>240</sup> Pu
<sup>144</sup> Pr	<sup>95</sup> Zr/Nb	<sup>244</sup> Cm
<sup>233</sup> U	<sup>252</sup> Cf	

## A.2 FUEL REPROCESSING FACILITIES

External exposures were primarily from high-energy betas and photons in the separations facilities associated with fission products (FP). Internal exposures, primarily associated with contamination incidents, could be due to FP and/or plutonium. The following mix of radionuclides (<sup>238</sup>Pu, <sup>239</sup>Pu, <sup>240</sup>Pu, and <sup>241</sup>Pu) comprises most plutonium mixtures at Hanford. The Hanford plutonium mixtures as shown in Tables A.2-3, A.2-4 and A.2-5 below were categorized by their weight percent of <sup>240</sup>Pu (Carbaugh, 2003). When the production reactors were operating, the target mixture was ~ 6% <sup>240</sup>Pu (i.e. weapons grade). A special study in the 1980's indicated frequent-intermittent releases of plutonium in the workplaces at levels below detectability for normal air sampling. This resulted in < 10 mrem CEDE (Bihl, 1993; Lyon, et al, 1988; Lyon, et al, 1989).

The new lung model for internal Dosimetry uses absorption types. The new types are F, M, S for fast, moderate, and slow. Plutonium in nitrate form is M, which would apply to the separations plants up to the point when N cell was started at PUREX. Plutonium Oxide is classed as type S. This would apply to material calcined at either N cell at PUREX. Type S at PUREX would apply only to N cell, not the

PR Room. Contamination remaining in old glove boxes, hood exhaust ducts, HEPA and sand filters and housings, etc., probably would be classed between M and S, but the default would be S. This is because plutonium slowly oxides. Plutonium at 233-S was type M up until 1967 when the fire resulted in the facility shutdown. The plutonium would be Type S by the time D&D was started at 233-S in the 1980s. It should be assumed after 1990 that all plutonium at Hanford would be class S because of natural oxidation. Note: The default solubility classes should be used only when bioassay data is inconclusive.

The B Plant facilities were modified in 1968 to remove <sup>90</sup>Sr and <sup>137</sup>Cs from high-level wastes from the single and double-shell waste tanks. The purified <sup>90</sup>Sr and <sup>137</sup>Cs solutions were transferred to the 225-B Waste Encapsulation Storage Facility (see section 2.2.6). The 221-B operated from 1968 to 1978 in support of this new mission. Internal exposures from the operation were minimal due to the remote operation. As a result of remote operation, external exposures to high-energy photons and beta particles resulting from the processing of large quantities of strontium and cesium were minimized. The 108-B Facility was used for the extraction of Tritium (<sup>3</sup>H) for several years. Internal exposure was related to tritium, which was added to whole body exposure (see External and Internal Dosimetry Sections).

Internal exposures at U and UO<sub>3</sub> plants were due to the large quantities of uranium processed. The contaminant could be found ranging from soluble uranyl nitrate and UO<sub>3</sub> to insoluble UO<sub>2</sub> and U<sub>3</sub>O<sub>8</sub>

The inhalation class for Hanford uranium compounds, based on ICRP 66, is shown in Table A.3-5 below.

The years of operation and radionuclides of concern are shown in Tables A.2-1 and A.2-2 below.

Table A.2-1. Fuel reprocessing facilities years of operation.

Separation Facility								
B	T	REDOX	PUREX	U	UO <sub>3</sub>	225-B	C	Tritium
4/1945-10/1952(a)	12/1944-Present (b)	1/1952-12/1967©	1/1956-12/1992 (d)	3/1952-1/1958	1/1952-1993(e)	19UNK - Present	1949*-1967(f)	8/1949 - 1955

- In 1968 B Plant started to remove Sr-90 and Cs-137 from high-level wastes; and shut down in 1978.
  - The T-Plant discontinued reprocessing operation in March 1956 (\*) and was utilized as a Decontamination Facility; The 2706-T Annex was added in 1959.
  - The 233-S facility located at REDOX started operation in 1957 and shutdown in 1967.
  - Closed in 6/72 and reopened in 11/83.
  - Shutdown in 1972 and opened again in 1983 (there were 17 start ups and shutdowns between 1984 and 1992)
  - Started operations in 1952 (?) as REDOX Pilot Plant; 1954 started operations as PUREX Pilot Plant; 1962 started operation as Pilot Plant for recovery of Cs and Sr waste tanks NOTE: date for d has not been resolved.
- \* More than one date was found  
UNK - No date found

Table A.2-2. Radionuclides of concern for all reprocessing facilities.

<sup>103</sup> Ru	<sup>235</sup> U
<sup>106</sup> Ru	<sup>237</sup> Np
<sup>131</sup> I	<sup>238</sup> U
<sup>137</sup> Cs	<sup>239</sup> Pu
<sup>140</sup> Ba/La	<sup>241</sup> Am
<sup>141</sup> Ce	<sup>3</sup> H
<sup>144</sup> Ce	<sup>60</sup> Co
<sup>233</sup> U	<sup>90</sup> Sr

1 Table A.2-3. Activity composition of Hanford reference weapons-grade plutonium mixture.

Mixture designation:	Fresh	5-Year	10-Year	15-Year	20-Year	25-Year	30-Year
Years of aging <sup>a</sup> :	0	5	10	15	20	25	30
Specific activity in mixture (Ci/g)							
<sup>238</sup> Pu	8.56E-03	8.23E-03	7.91E-03	7.60E-03	7.31E-03	7.03E-03	6.75E-03
<sup>239</sup> Pu	5.77E-02	5.77E-02	5.77E-02	5.77E-02	5.77E-02	5.77E-02	5.77E-02
<sup>240</sup> Pu	1.36E-02	1.36E-02	1.36E-02	1.36E-02	1.36E-02	1.36E-02	1.36E-02
<sup>241</sup> Pu	8.24E-01	6.48E-01	5.09E-01	4.00E-01	3.15E-01	2.48E-01	1.95E-01
<sup>242</sup> Pu	1.97E-06	1.97E-06	1.97E-06	1.97E-06	1.97E-06	1.97E-06	1.97E-06
<sup>241</sup> Am	0	5.83E-03	1.04E-02	1.39E-02	1.66E-02	1.87E-02	2.03E-02
<sup>239+240</sup> Pu	7.13E-02	7.13E-02	7.13E-02	7.13E-02	7.12E-02	7.12E-02	7.12E-02
Pu-alpha	7.99E-02	7.95E-02	7.92E-02	7.89E-02	7.85E-02	7.83E-02	7.80E-02
Total alpha	7.99E-02	8.53E-02	8.96E-02	9.28E-02	9.52E-02	9.70E-02	9.83E-02
Activity ratios							
<sup>239+240</sup> Pu: <sup>241</sup> Am	NA	12.2	6.87	5.13	4.28	3.80	3.50
<sup>239+240</sup> Pu: <sup>238</sup> Pu	8.33	8.67	9.01	9.38	9.74	10.1	10.5
<sup>241</sup> Pu: <sup>239+240</sup> Pu	11.6	9.09	7.15	5.62	4.42	3.48	2.73
Pu alpha: <sup>239+240</sup> Pu	1.12	1.20	1.26	1.30	1.34	1.36	1.38
Pu alpha: <sup>238</sup> Pu	9.33	9.66	10.0	10.4	10.7	11.1	11.6
Pu alpha: <sup>241</sup> Am	NA	14.6	8.63	6.67	5.72	5.18	4.84
<sup>241</sup> Pu: Pu alpha	10.3	8.15	6.43	5.07	4.01	3.17	2.50

2 a. Time since separation of <sup>241</sup>Am from the Pu mix.

3 Table A.2-4. Activity composition of Hanford reference fuel-grade plutonium mixture.

Mixture designation:	Fresh	5-Year	10-Year	15-Year	20-Year	25-Year	30-Year
Years of aging <sup>a</sup> :	0	5	10	15	20	25	30
Specific activity in mixture (Ci/g)							
<sup>238</sup> Pu	1.71E-02	1.64E-02	1.58E-02	1.52E-02	1.46E-02	1.40E-02	1.35E-02
<sup>239</sup> Pu	5.26E-02	5.26E-02	5.26E-02	5.26E-02	5.26E-02	5.26E-02	5.25E-02
<sup>240</sup> Pu	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.71E-02	2.71E-02
<sup>241</sup> Pu	3.09E+00	2.43E+00	1.91E+00	1.50E+00	1.18E+00	9.29E-01	7.30E-01
<sup>242</sup> Pu	3.93E-06	3.93E-06	3.93E-06	3.93E-06	3.93E-06	3.93E-06	3.93E-06
<sup>241</sup> Am	0	2.19E-02	3.89E-02	5.22E-02	6.24E-02	7.03E-02	7.63E-02
<sup>239+240</sup> Pu	7.98E-02	7.98E-02	7.98E-02	7.97E-02	7.97E-02	7.97E-02	7.97E-02
Pu-alpha	9.69E-02	9.62E-02	9.56E-02	9.49E-02	9.43E-02	9.37E-02	9.32E-02
Total alpha	9.69E-02	1.18E-01	1.35E-01	1.47E-01	1.57E-01	1.64E-01	1.69E-01
Activity ratios							
<sup>239+240</sup> Pu: <sup>241</sup> Am	NA	3.64	2.05	1.53	1.28	1.13	1.04
<sup>239+240</sup> Pu: <sup>238</sup> Pu	4.67	4.86	5.05	5.24	5.46	5.69	5.90
<sup>241</sup> Pu: <sup>239+240</sup> Pu	3.87	3.05	2.40	1.88	1.48	1.17	0.91
Pu alpha: <sup>239+240</sup> Pu	1.21	1.21	1.20	1.19	1.18	1.18	1.17
Pu alpha: <sup>238</sup> Pu	5.67	5.87	6.05	6.24	6.46	6.69	6.90
Pu alpha: <sup>241</sup> Am	NA	4.39	2.46	1.82	1.51	1.33	1.22
<sup>241</sup> Pu: Pu alpha	31.9	25.3	20.0	15.8	12.5	9.91	7.83

4 a. Time since separation of the <sup>241</sup>Am from the Pu mix.

5



Table A.2-5. Activity composition of Hanford reference commercial power fuel-grade plutonium mixture.

Mixture designation:	Fresh	5-Year	10-Year	15-Year	20-Year	25-Year	30-Year
Years of aging <sup>a</sup> :	0	5	10	15	20	25	30
Specific activity in mixture (Ci/g)							
<sup>238</sup> Pu	1.71E-01	1.64E-01	1.58E-01	1.52E-01	1.46E-01	1.40E-01	1.35E-01
<sup>239</sup> Pu	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02
<sup>240</sup> Pu	5.90E-02	5.89E-02	5.89E-02	5.89E-02	5.89E-02	5.88E-02	5.88E-02
<sup>241</sup> Pu	1.34E+01	1.05E+01	8.28E+00	6.51E+00	5.12E+00	4.03E+00	3.17E+00
<sup>242</sup> Pu	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04
<sup>241</sup> Am	0	9.49E-02	1.69E-01	2.26E-01	2.79E-01	3.04E-01	3.31E-01
<sup>239+240</sup> Pu	9.31E-02	9.31E-02	9.30E-02	9.30E-02	9.29E-02	9.29E-02	9.29E-02
Pu-alpha	2.65E-01	2.58E-01	2.52E-01	2.45E-01	2.39E-01	2.34E-01	2.28E-01
Total alpha	2.65E-01	3.53E-01	4.20E-01	4.71E-01	5.10E-01	5.38E-01	5.59E-01
Activity Ratios							
<sup>239+240</sup> Pu: <sup>241</sup> Am	NA	0.981	0.551	0.411	0.344	0.305	0.281
<sup>239+240</sup> Pu: <sup>238</sup> Pu	0.544	0.568	0.589	0.612	0.636	0.664	0.688
<sup>241</sup> Pu: <sup>239+240</sup> Pu	144	113	89.1	70.0	55.1	43.3	34.1
Pu alpha: <sup>239+240</sup> Pu	2.85	2.77	2.71	2.63	2.57	2.52	2.45
Pu alpha: <sup>238</sup> Pu	1.55	1.57	1.59	1.61	1.64	1.67	1.69
Pu alpha: <sup>241</sup> Am	NA	2.72	1.49	1.08	0.857	0.770	0.689
<sup>241</sup> Pu: Pu alpha	50.6	40.7	32.9	26.6	21.4	17.2	13.9

a. Time since separation of the <sup>241</sup>Am from the Pu mix.

### A.3 FUEL FABRICATION FACILITIES

External exposures were related to betas and photons associated with uranium. Due to the pyrophoric nature of uranium turnings and chips, internal exposure was related primarily to inhalation of uranium. A pressurization of one of the sealed metal storage cans resulted in the spread of plutonium contamination and the subsequent shut down of the building until cleanup. The years of operation and radionuclides of concern are shown in Tables A.3-1 and A.3-2 below. The radiological characteristics of Hanford uranium mixtures are shown in Table A.3-3 and the impurities in recycled Hanford uranium are shown in Table A.3-4. The inhalation class for Hanford uranium compounds is shown in Table A.3-5. Note: The default solubility classes should be used only when bioassay data is inconclusive.

Table A.3-1. Fuel fabrication facilities years of operation.

Fuel fabrication				
313	314	333	303 Facilities	306
3/1944 –1/1971	7/1944 -1971	1961 -1988	1944 - Present	5/1957 -1984

Table A.3-2. Radionuclides of concern for all fuel fabrication and storage facilities.

<sup>241</sup> Am	<sup>237</sup> Np	<sup>238</sup> Pu	<sup>239</sup> Pu	<sup>232</sup> Th	<sup>235</sup> U	<sup>238</sup> U
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Table A.3-3. Radiological characteristics of Hanford uranium mixtures.

Uranium mixture				
Weight percentage <sup>a,b</sup>	Natural (NU)	Depleted (DU)	Recycled (RU)	Commercial fuel (CF)
<sup>234</sup> U	0.0057	0.0005	0.0082	0.0300
<sup>235</sup> U	0.7204	0.2500	0.9700	2.9600
<sup>236</sup> U	Negligible	Negligible	0.0680	Negligible
<sup>238</sup> U	99.2739	99.7500	98.9500	97.0100
Specific constituent activity in mixture (uCi/g, nCi/mg, or pCi/ug) <sup>c</sup>				
<sup>234</sup> U	0.3563	0.0313	0.5125	1.8750
<sup>235</sup> U	0.0156	0.0054	0.0210	0.0639
<sup>236</sup> U	Negligible	Negligible	0.0440	Negligible
<sup>238</sup> U	0.3336	0.3352	0.3325	0.3260
Total	0.7054	0.3718	0.9099	2.2649
Specific constituent activity in mixture (dpm/ug) <sup>c</sup>				
<sup>234</sup> U	0.7909	0.0694	1.1378	4.1625
<sup>235</sup> U	0.0345	0.0120	0.0465	0.1419
<sup>236</sup> U	Negligible	Negligible	0.0977	Negligible
<sup>238</sup> U	0.7405	0.7441	0.7381	0.7236
Total	1.5659	0.8254	2.0200	5.0281
Constituent fraction of total uranium activity in mixture				
<sup>234</sup> U	0.5051	0.0840	0.5632	0.8279
<sup>235</sup> U	0.0221	0.0145	0.0230	0.0282
<sup>236</sup> U	Negligible	Negligible	0.0484	Negligible
<sup>238</sup> U	0.4729	0.9014	0.3654	0.1439
Total	1.0000	1.0000	1.0000	1.0000

- a. NU, DU, and CF data from Rich et al, 1988.  
b. RU data based on average of data presented by Sula, et al, 1991.  
c. Can be used to represent specific alpha activity in the mixture as well.

Table A.3-4. Impurities in recycled uranium at Hanford.

Constituent	Maximum allowed <sup>a</sup>	Observed range <sup>b</sup>	Reference level <sup>c</sup>
Plutonium	10 ppb U	<1 - 2 ppb U	0.4 nCi Pu-alpha/gU
Neptunium	Not established	0.04-0.16 ppm U	0.4 nCi <sup>237</sup> Np/g U
Thorium	750 ppm U	8 - 10 ppm U	5 pCi <sup>232</sup> Th/g U
<sup>99</sup> Tc	Not established	3 - 4 ppm U	0.2 uCi <sup>99</sup> Tc/g U
<sup>103,106</sup> Ru	<20 uCi/lb U	<6 uCi/lb U	40 nCi <sup>106</sup> Ru/g U
<sup>95</sup> ZrNb	<10 uCi/lb U	<4 uCi/lb U	20 nCi <sup>95</sup> ZrNb/g U
Other gamma emitters excluding <sup>99</sup> Tc	<2 uCi/lb U	0.09 0.75 uCi/lbU	Negligible

- a. From UO3 Plant operating specifications, OSD-U-185-0001 (Thompson 1986).  
b. From analysis of uranium lots 88-1, 88-2, 88-3 that was processed in 1988, and lots 93-01, 93-02, 93-03, 93-04, and 93-05, processed in 1993.  
c. A reference level is chosen for determining bioassay-monitoring needs and for use as an initial assumption in evaluating intakes. The use of the reference levels is expected to result in a slight overestimate of dose compared to levels actually observed in 1988.

1 Table A.3-5. Inhalation class for Hanford uranium compounds.

ICRP 30 inhalation class from lung fluid studies	Compound and location	Recommended ICRP 66 lung absorption type <sup>d</sup>
80% D 20% W	Hanford UO <sub>3</sub> Plant smear sample dissolution study in 1984 <sup>a</sup> , (UO <sub>3</sub> powder)	F
10% D 90% Y	Hanford 303-M Building air sample dissolution study <sup>b</sup> (300 Area Uranium Fuel Production Facilities)	S
29% D 71% Y	Hanford 333 Building air sample dissolution study <sup>b</sup> (300 Area Uranium Fuel Production Facilities)	S
20% D 80% Y	Hanford 306-W Building Machine Shop air sample dissolution study <sup>b</sup>	S
	Uranyl nitrate at Purex or UO <sub>3</sub> Plant	F
	UCl <sub>4</sub> or U carbonate (assumed form after discharge to the soil)	M <sup>c</sup>

2 a. Sula, Bihl, and Carbaugh (1989).

3 b. Fisher, (1986).

4 c. Cooke and Holt 1974.

5 d. Note: The default solubility classes should be used only when bioassay data is inconclusive.

## 6 A.4 PLUTONIUM FINISHING FACILITIES

7 Although relatively few Hanford personnel were involved in plutonium finishing, these facilities  
8 provided the majority of personnel external exposures to neutron radiation. As production increased,  
9 ten-inch thick water-filled walls were installed to reduce worker exposure to neutrons. Special lead-  
10 filled gloves were installed to reduce extremity exposure. Worker external exposure in the vault  
11 rooms was due to low-energy photons and neutrons that occurred during periodic inventory and  
12 inspection activities.

13 Internal exposures in the operating areas were related primarily to contamination incidents involving  
14 americium and plutonium since airflow patterns were designed to control the flow from areas of lower  
15 air contamination potential to higher. Maintenance and clean-up operations were conducted in  
16 protective clothing including respiratory protection. Exposures occurred by inhalation, absorption and  
17 injection (i.e. wound sites). Internal exposure in the vault areas was minimal since there were no  
18 routine activities that involved opening the storage containers. Internal exposure would have been a  
19 concern in the event of an incident that breached the containment.

20 In Feb. 1960, RECUPLEX was temporarily shut down to permit an extensive cleanup of hoods and  
21 operating equipment. A criticality accident that occurred in the RECUPLEX facility in April 1962  
22 resulted in high external radiation exposures and in widespread contamination throughout the  
23 RECUPLEX room.

24 The new lung model for internal Dosimetry uses absorption types. The new types are F, M, S for fast,  
25 moderate, and slow. Plutonium in nitrate form is M, which would apply to the plutonium finishing  
26 plants where plutonium nitrate has been involved (e.g. RECUPLEX, 231-Z, etc.). Plutonium Oxide  
27 that is classed as type S, would apply to material calcined at the RMC line at PFP. Contamination  
28 remaining in old glove boxes, hood exhaust ducts, HEPA and sand filters and housings, etc., probably  
29 would be classed between M and S, but the default would be S. This is because plutonium slowly  
30 oxides. It should be assumed after 1990 that all plutonium at Hanford would be class S because of  
31 natural oxidation. In a study performed in the early 1990's of the isotopic distribution of plutonium at  
32 PFP, it was stated there were ~3.7 million grams of plutonium with the <sup>240</sup>Pu content ranging from 4%  
33 to >19% (Crowe, Szempruch 1994). Note: The default solubility classes should be used only when  
34 bioassay data is inclusive.

The years of operation and the radionuclides of concern are listed in Tables A.4-1 and A.4-2 below. The activity composition for Hanford reference plutonium mixtures is shown in Tables A.2-3, A.2-4, and A.2-5 above.

Table A.4-1. Plutonium finishing facilities years of operation.

Facility/process								
231-Z	232-Z	2345Z RG	2345Z RMA	2345Z RMC	2345Z RECUPLEX	2345Z Storage vault	236-Z	242-Z
1/1945 - 19UNK( a)	1/1962 - 1973	7/1949 - 1957	3/1952 - 1984(b)	10/1960 - 1989(c)	7/1955 - 1/1962	1949 -Present	5/1964 - 4/1976( d)	1963 - 1976(e)

- In 1956 the mission changed to plutonium metallurgy development: In 19UNK <sup>233</sup>U metallurgy studies were undertaken.
- In 1964 line shutdown: In 1967 a glove box was reactivated; In 1968, Tasks I-III were cleaned out and reactivated; In 1984 it was decided to keep the RMA on standby.
- In 1962 ten-inch thick water-filled shielding tanks were added to substantially reduce operator exposure to neutrons; Several safety improvements made in 1963 and 1964; Fabrication of pits removed from line in 1966. Shutdown in 1976 as a result of explosion in 242-Z; The RMC line restarted in 1985; Shut down in 1989.
- In 12/1975 it was shutdown for upgrades; Restarted in 1976; Shut down in 4/1976 as a result of explosion in 242-Z.
- In 1969 changed from batch to continuous process; In 4/1976 shut down because of strike; In 8/1976 restarted; Shut down in 8/1976 as a result of explosion in americium recovery area.

Table A.4-2. Radionuclides of concern for plutonium finishing facilities.

<sup>233</sup> U	<sup>237</sup> Np	<sup>238</sup> Pu	<sup>239</sup> Pu	<sup>240</sup> Pu	<sup>241</sup> Pu	<sup>242</sup> Pu	<sup>241</sup> Am
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## A.5 RESEARCH AND DEVELOPMENT FACILITIES

The 21-major Research, Development, and Testing Facilities at Hanford were located in the 100, 200 and 300 Areas. Construction of these started in 1944 with the last one completed in 1977. These facilities were built to support the development and testing of new processes, materials, and equipment. In some instances the facilities were used for several different purposes throughout their operating life. Therefore, the potential exposures are dependent on the processes involved and the mission/process at any given time. See sections 2.5.1 through 2.5.21 for discussion on internal and external exposure potential at specific facilities. The years of operation and the radionuclides of concern are listed in Tables A.5-1, A.5-2, and A.5-3 below.

Table A.5-1. 100 and 200 Area research and development facilities years of operation.

Facility/process					
108-F	120	209-E	222-B	222-S	222-T
1949 -1977	4/1950 - 11/1951	7/1961 -19860*	1945 -1975	1949 -present	1944 -1986**

\*Only decade date found

\*\*More than one date found

Table A.5-2. 300 Area research and development facilities years of operation.

Facility/process						
308	318	320	321	324	325	326
1960 -1990 <sup>a</sup>	1983 - Present <sup>b</sup>	1966 - Present	1944 -1988 <sup>c</sup>	1966 - Present	1953 - Present <sup>d</sup>	1953 - Present

Table A.5-3. 300 Area research and development facilities years of operation (continued).

Facility/process							
327	329	331	3706	3730	3732	3741	3745
1953 - 1987	1952 - Present	1972 - Present	1945 - late 1960's <sup>e</sup>	1949 - 1981	1949 - 1970	1944 - 1956	10/1944 - 1983 <sup>f</sup>

- In mid 1960's PRTR fuel work was terminated; Np-Al alloy fuel elements produced in late 1960's; High bay area added in 1971; From 1977-1991 FFTF fuel elements were produced; The 308A annex was added in 1979; Triga reactor was installed in the late 1970's.
- The HTLTR reactor commenced operation in the 318 building in 1967; The reactor was shut down in 19UNK; The reactor was removed in the early 1980's; The calibration facility commenced operation in 1983; Major additions were added in 1986, 1987, and 1989.
- The 321 separation building started in 1944; In late 1944 work with small amounts of irradiated materials to conduct separations experiments and to study decontamination factors; in 1949 a cold test of REDOX process was performed; A cold test of the PUREX process was tested in 1953.
- The 325-A hot cell wing was added in 1959\*; Pm-147 heat sources manufactured in 1966; Po-210 work started in 6/1972 and ended in 1970\*. For use with the demonstration of the Waste Vitrification Process for commercial wastes.
- Most of the radiation laboratories were removed in 1954; Work with radioactive materials discontinued in late 1960's; building converted to offices in the 1970's and still in use in the early 1990's.
- The 3745-B annex that housed a 4 MV Positive Ion Accelerator started operation in 1955; The 3745-A annex that housed a 2 MV Negative Ion Accelerator started operation in 1950\*; The calibrations operations were transferred to the 318 building in 1983; The building is being used as offices.

Table A.5-4. Radionuclides of concern for all 100, 200, and 300 Area research and development facilities.

<sup>14</sup> C	<sup>147</sup> Pm
<sup>144</sup> Ce	<sup>238</sup> Pu
<sup>60</sup> Co	<sup>239</sup> Pu
<sup>137</sup> Cs	<sup>103</sup> Ru
<sup>64</sup> Cu	<sup>106</sup> Ru
FP	<sup>90</sup> Sr
<sup>131</sup> I	<sup>238</sup> U
<sup>235</sup> U	<sup>90</sup> Y

## A.6 WASTE FACILITIES

External exposure is related to high-energy beta and photon radiations from the fission products stored in the tanks. Under normal conditions shielding, distance and time helped keep personnel external exposures at a low level. Leaks of high-level wastes that could result in unusual or unplanned external exposures were documented in incident or accident reports. In 1994, data was included in (Boomer, et al 1994) on tank waste radionuclide inventory. The data from that report are included in Table A.6-3. Internal exposures to FP were controlled through the use of respiratory protection.

A mining operation to remove an estimated 45 kg of plutonium from the Z-9 trench was initiated in Aug. 1976 and was completed in July 1978. The principal internal exposure potential was related to <sup>239</sup>Pu contamination, most of which occurred in the soil packaging glove box. Since the waste site was used only for plutonium, the external exposure potential during the mining operation was minimal.

The years of operation and radionuclides of concern are shown in Tables A.6-1 and A.6-2 below.

1 Table A.6-1. Waste facilities years of operation.

Facility/Process					
Waste Tanks	Z-9 Trench Facility	241-Z	242 Evaporator Facilities	Exhaust Filtration Facilities	340 Waste Complex
1944 -Present	1955 -1978	1949 -1973	1951 -Present	1947 -19UNK	1954 -Present

2 Table A.6-2. Radionuclides  
3 of concern for all waste  
4 facilities.

<sup>141</sup> Ce	<sup>238</sup> Pu
<sup>144</sup> Ce	<sup>239</sup> Pu
<sup>60</sup> Co	<sup>103</sup> Ru
<sup>137</sup> Cs	<sup>106</sup> Ru
FP	<sup>90</sup> Sr
<sup>131</sup> I	<sup>90</sup> Y
<sup>147</sup> Pm	

5 Table A.6-3. Tank waste radionuclide inventory.

Mega curies of radioactive specie	Liquid components		Solid components	
	Double-shell tanks	Single-shell tanks	Double-shell tanks	Single-shell tanks
<sup>137</sup> Cs and <sup>137</sup> Ba	6.40 E+01	2.53 E+01	2.33 E+00	8.45 E+00
<sup>90</sup> Sr and <sup>90</sup> Y	3.93 E+00	1.14 E+01	2.17 E+01	1.13 E+02
<sup>99</sup> Tc	2.28 E-02	7.82 E-03	1.35 E-03	7.82 E-03
<sup>241</sup> Am	1.45 E-02	4.70 E-03	7.97 E-02	4.23 E-02
<sup>237</sup> Np	1.64 E-05	3.30 E-06	1.92 E-05	2.97 E-05
Pu	3.84 E-03	5.50 E-04	6.80 E-03	2.69 E-02
TRU	1.93 E-02	5.25 E-03	9.10 E-02	6.92 E-02

6